A Geostatistical study for
Geology - Energy - Mineral Resources
in the Califonia Desert

Appendix B - Geological and Geophysical
Data for the CDCA

A GEOSTATISTICAL STUDY FOR GEOLOGY - ENERGY - MINERAL RESOURCES IN THE CALIFORNIA DESERT

- APPENDIX B -
GEOLOGICAL AND GEOPHYSICAL DATA FOR THE CDCA

TERRADATA

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- Gravity data provided for most of the CDCA by Dr. Shawn Biehler of the University of California at Riverside. These are supplemented with gravity data from the "Bouguer Gravity Map, Kingman Sheet" published by the California Division of Mines and Geology.

Aeromagnetic data are available for some areas within the CDCA. However, the quality of the data varies and involves differing assumptions for mathematical reduction. Therefore, considering the necessity for coverage of uniform quality for a regional statistical analysis, it is not feasible to use the existing aeromagnetic data.

The data (except for Bouguer gravity values) were compiled for each 2 km by 2 km square in the CDCA. There are 26,812 such cells in the CDCA. Once the data were compiled by hand and encoded onto a computer tape, they were merged into larger cells 4 km x 4 km square for geostatistical purposes.

Tables B-1, B-2 and B-3 list the geological and geophysical variables used for the analysis.

Table B-1

GEOLOGIC AND GEOPHYSICAL VARIABLES FOR THE CDCA

Lithologic Units

Variable Number	Description	Areal Extent Within CDCA (km^2)	% Of CDCA Area
1.	Precambrian granitic rocks. - Precambrian anorthosite. - Undivided Precambrian granitic rocks.	701	0.67
2.	Precambrian metamorphic rocks. - Precambrian igneous and metamorphic rock complex. - Earlier Precambrian metamorphic rocks. - Later Precambrian sedimentary and metamorphic rocks. - Undivided Precambrian metamorphic rocks.	5,542	5.28
3.	Cambrian and late Precambrian sedimentary rocks. - Cambrian and Precambrian marine. - Cambrian marine.	1,963	1.87
4.	Ordovician through Mississippian marine sedimentary rocks. - Ordovician marine. - Pre-Silurian metasedimentary rocks. - Silurian marine. - Devonian marine. - Mississippian marine. - Paleozoic marine.	2,318	2.21
5.	Pennsylvanian through Permian marine sedimentary rocks. - Pennsylvanian marine. - Undivided carboniferous marine. - Permian marine.	489	0.47
6.	Pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks.	1,298	1.24
7.	Paleozoic and Precambrian metavolcanic rocks. - Pre-Silurian metamorphic rocks. - Pre-Silurian metavolcanic rocks. - Devonian and pre-Devonian metavolcanic rocks. - Devonian metavolcanic rocks. - Carboniferous metavolcanic rocks. - Permian metavolcanic rocks. - Paleozoic metavolcanic rocks.	14	0.01

Table B-1 (continued)

8.	Triassic-Jurassic marine sediments. - Triassic marine. - Middle and/or Lower Jurassic marine. - Upper Jurassic marine. - Knoxville Formation.	28	0.03
9.	Pre-Cretaceous metavolcanic rocks (if age cannot be established other than pre-Cretaceous). - Pre-Cretaceous metavolcanic rocks. - Jura-Triasic metavolcanic rocks.	472	0.45
10.	Mesozoic basic intrusives. - Mesozoic ultrabasic intrusive rocks. - Mesozoic basic intrusive rocks.	277	0.26
11.	Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks.	14,431	13.76
12.	Eolian deposits.	3,271	3.12
13.	Tertiary sediments (marine and non-marine).	2,860	2.73
14.	Tertiary igneous intrusives (hypabyssal).	515	0.49
15.	Tertiary volcanics. - Eocene volcanics. - Oligocene volcanics. - Miocene volcanics. - Pliocene volcanics.	5,142	4.90
16.	Quaternary sediments. - Plio-Pleistocene non-marine. - Pleistocene non-marine. - Pleistocene marine and marine terrace deposits. - Quaternary non-marine terrace deposits. - Glacial deposits. - Salt deposits. - Basin deposits. - Fan deposits. - Stream channel deposits. - Alluvium.	61,815	58.93
17.	Quaternary volcanics. - Pleistocene volcanics. - Recent volcanics.	1,652	1.57
18.	Bodies of water and unmapped areas.	2,112	2.01
	TOTAL	104,900	100.0

Table B-2
GEOLOGICAL AND GEOPHYSICAL VARIABLES FOR THE CDCA
Rock Contact Relationships

Variable Number	Description	Total Length In CDCA (Km)
19	Length of contact between Precambrian granitic rocks (1) and Precambrian metamorphic rocks (2).	481.0
20	Length of contact between Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11), and either Ordovician through Mississippian marine sedimentary rocks (4), or Pennsylvanian through Permian marine sedimentary rocks (5).	565.0
21	Length of contact between Mesozoic granitic intrusions and pre-Cenozoic granitic and metamorphic rocks (11) and Triassic-Jurassic marine sediments (8).	1.6
22	Length of contact between Tertiary igneous intrusives (14) and Precambrian granitic rocks (1).	0.8
23	Length of contact between Tertiary igneous intrusives (14) and Precambrian metamorphic rocks (2).	53.2
24	Length of contact between Tertiary igneous intrusives (14) and Cambrian and late Precambrian sedimentary rocks (3).	3.2
25	Length of contact between Tertiary igneous intrusives (14) and Ordovician through Mississippian marine sedimentary rocks (4).	5.2
26	Length of contact between Tertiary igneous intrusives (14) and Pennsylvanian through Permian marine sedimentary rocks (5).	9.6
27	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metasedimentary rocks and pre-Cretaceous metamorphic rocks (6).	7.2
28	Length of contact between Tertiary igneous intrusives (14) and Paleozoic and Precambrian metavolcanic rocks (7).	2.8
29	Length of contact between Tertiary igneous intrusives (14) and Triassic-Jurassic marine sediments (8).	2.8
30	Length of contact between Tertiary igneous intrusives (14) and pre-Cretaceous metavolcanic rocks (9).	2.8
31	Length of contact between Tertiary igneous intrusives (14) and Mesozoic basic intrusives (10).	4.8
32	Length of contact between Tertiary igneous intrusives (14) and Mesozoic granitic intrusives and pre-Cenozoic granitic and metamorphic rocks (11).	208.0
33	Length of contact between Tertiary igneous intrusives (14) and eolian deposits (12).	0.1
34	Length of contact between Tertiary igneous intrusives (14) and Tertiary sediments (13).	83.0

Table B-3

GEOLOGICAL AND GEOPHYSICAL VARIABLES
AND NUMBER OF SUBCELLS
FOR THE CDCA

Structural Relationships

Variable Number	Description	Total In CDCA
35.	Length of thrust faults (km).	518
36.	Number of thrust faults.	415
37.	Length of non-thrust faults (km).	14,907
38.	Number of non-thrust faults.	12,629
39.	Number of fault intersections.	1,889
40.	Curvature of faults.	n/a
41.	Gravity value measured at cell center.	n/a
42.	Number of subcells.	26,812

2. SELECTION OF GEOLOGIC VARIABLES

The geological and geophysical variables selected for encoding and subsequent analysis as listed in Tables B-1, B-2, and B-3 were selected for two principle reasons:

1. The presence of these variables on the 1:250,000 CDMG Geologic Map of California, and

2. Their potential efficacy as measures of the regional geology, upon which subsequent statistical prediction of mineral occurrences have been based.

The variables listed in Table B-1 are referred to by number for convenience. Variables 1 through 18 represent lithologic map units from the geologic maps that have areal extent. Variables 19 through 35, and variable 37, have linear extent. The remaining variables (36 and 38 through 41) pertain to quantities that are neither linear nor areal. Variable 41 consists of Bouguer gravity. Variable 42, the number of subcells, was used for computational convenience only.

As noted in Table B-1, several lithologic units available from the geologic maps were combined into one variable for this study. For example, variable 4 is a combination of 6 lithologic units. These units were combined because they form similar environments for G-E-M occurrences. In addition, each variable used in geostatistical analysis should be present in sufficient quantity to be statistically meaningful. Not all of the variables listed in Tables B-1, B-2, and B-3 occur in significant proportions within the area of the CDCA. Variables 7 and 8 are only rarely present within the CDCA (less than 0.1 percent of total area), and were not incorporated in the geostatistical analyses, but were encoded where present. Similarly, variables 21 through 31, plus variable 33, are so infrequently present (less than 60 km in total) that they were not incorporated in the geostatistical analyses, although they are encoded in the overall data base where present.

3. GRID SYSTEM FOR RECORDING DATA

The base maps used for the California Desert Planning project are the U.S. Geological Survey Map series V502, Universal Transverse Mercater (UTM) Projection, scale 1:250,000. With the UTM grid system, any location can be uniquely identified as shown below and in Figure B-1. Figure B-2 shows the UTM Blocks for the CDCA. UTM locations are defined by the following:

$$\text{NNA BB } M_1M_2M_3M_4 \; L_1L_2L_3L_4$$

where:

NNA - is the grid zone designator (The entire CDCA is in grid zone 11S. It is, therefore, not coded)

BB - is the 100,000 meter square identifier or "UTM Block"

M - is the easting distance from the zero line of the UTM block

- M_1 - is tens of kilometers
- M_2 - is kilometers
- M_3 - is hundreds of meters
- M_4 - is tens of meters

(NOTE: if only 2 Ms appear it is assumed they are M_1 and M_2.)

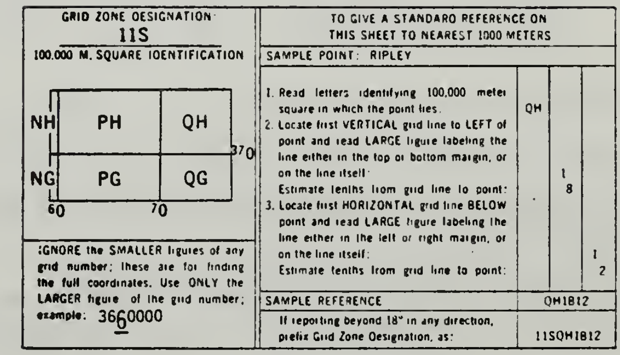
L - is the northing distance from the zero line of the UTM block.

- L_1 - is tens of kilometers
- L_2 - is kilometers
- L_3 - is hundreds of meters
- L_4 - is tens of meters

(NOTE: if only 2 Ls appear, it is assumed they are L_1 and L_2).

For the purpose of recording geological and geophysical data, each UTM block is divided in cells of 2 km square. There are 50 x 50 = 2500 such cells per UTM block. A unique identifier for each cell is the two letter UTM block, a two digit column number and a two digit row number. Figure B-3 illustrates the cell numbering system.

Figure B-1
EXPLANATION OF UTM SYSTEM*



SALTON SEA, CALIF.; ARIZ.
1959
REVISED 1969

* Copied from the Salton Sea, California; and Arizona Map Sheet (Reference 56).

Figure B-2

MAP OF CDCA SHOWING UTM BLOCKS

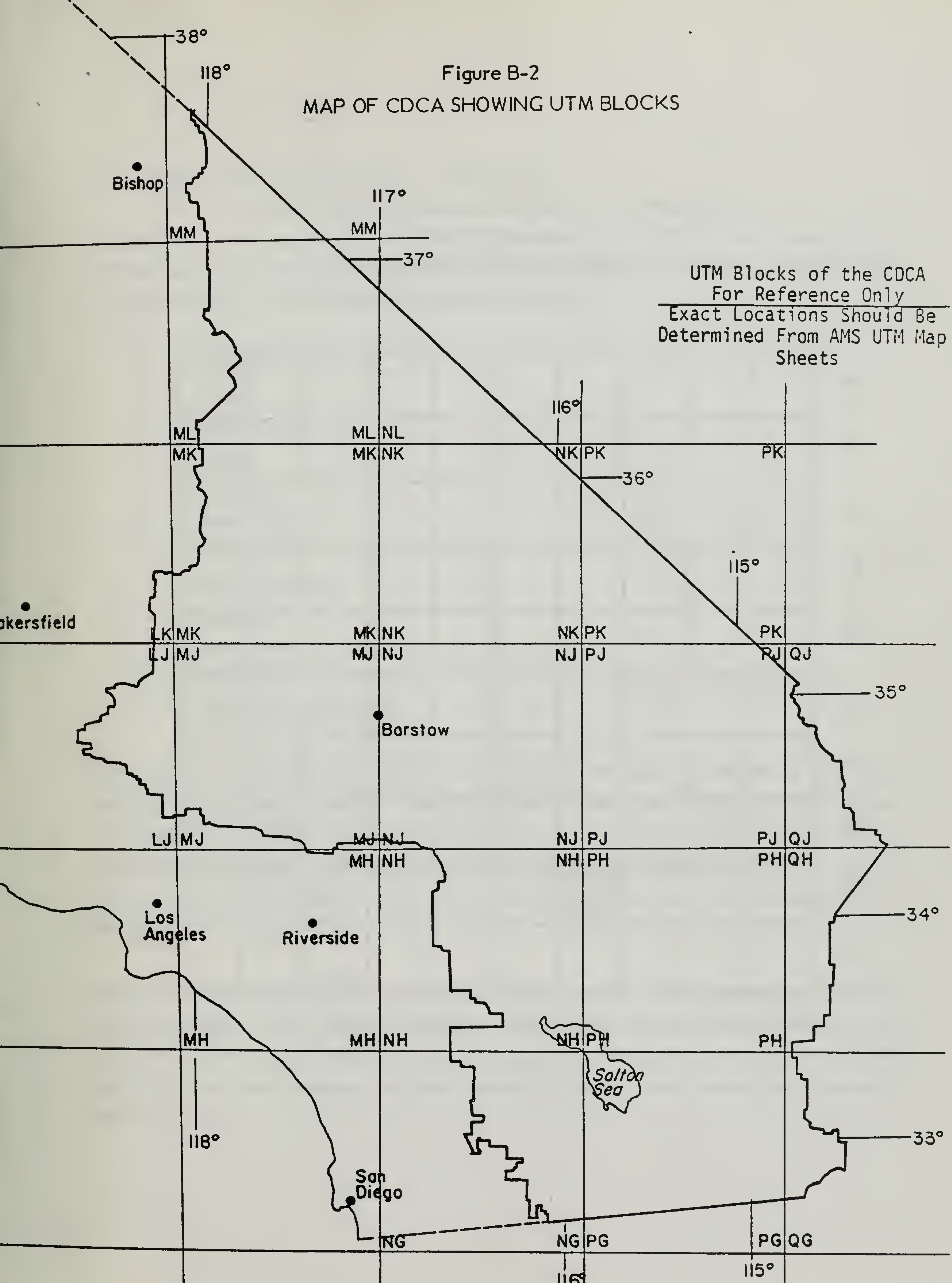


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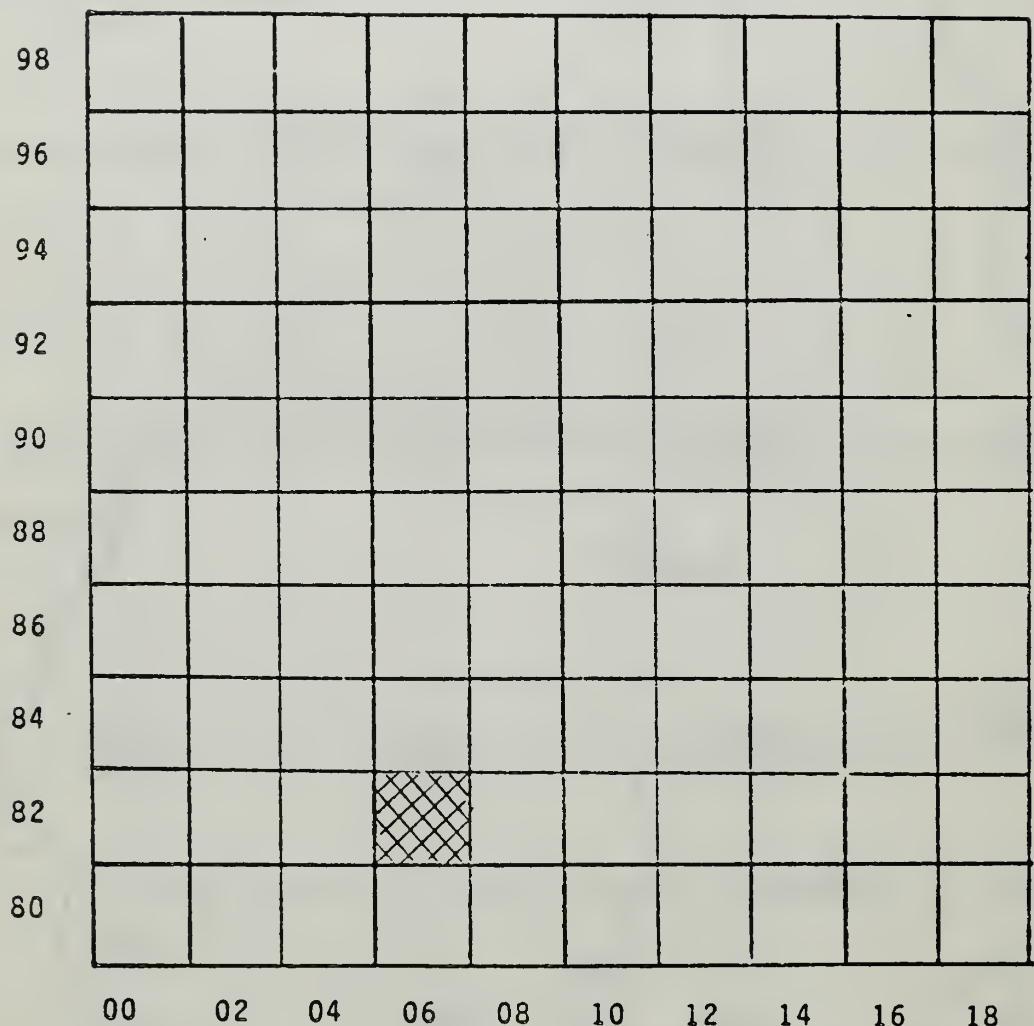
Figure B-3
PORTION OF A UTM BLOCK DIVIDED INTO CELLS
UTM BLOCK PG
(Hatched cell is PG0682)



4. USE OF GEOLOGIC MAPS

Except for a small portion of the Death Valley sheet, the 1:250,000 scale Geologic Maps of California, published by the California Division of Mines and Geology (CDMG) cover the entire CDCA. The following map sheets were used:

- Mariposa
- Fresno
- Death Valley
- Trona
- Kingman
- Bakersfield
- Los Angeles
- San Bernardino
- Needles
- Santa Ana
- Salton Sea
- San Diego - El Centro

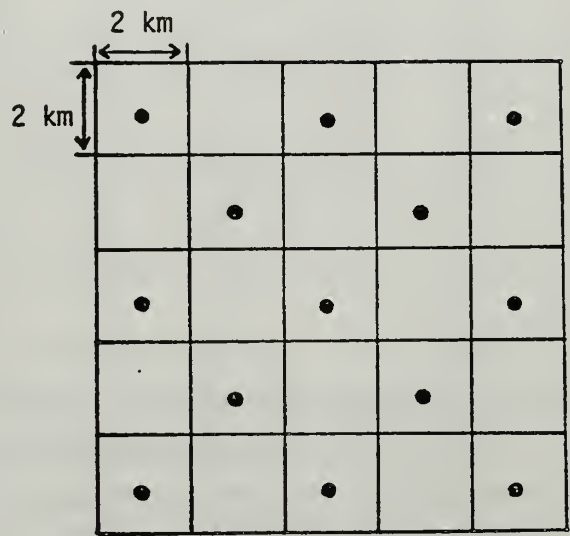
Since geologic maps are the basis for the geological variables as defined by this study, map scale influences accuracy. The detail of each map sheet depends upon the amount of information available and the professional interpretations employed at the time of compilation, the drafting techniques used, the accuracy of reproduction and the scale of the map. In general, larger scales allow more accurate and detailed representation of the geology.

Portions of the CDCA are covered by geologic maps at scales larger than 1:250,000 (References 83 - 115). These maps were used to check the interpretation of the 1:250,000 CDMG maps. However, these larger-scale maps were not used for encoding geological variables because different degrees of detail would introduce a degree of statistical bias.

5. GRAVITY DATA

The gravity data received from Dr. Shawn Biehler, University of California at Riverside, consist of Bouguer gravity in milligals as computed at points that form a diamond pattern (see Figure B-4 below) for most of the CDCA. We received no gravity data for entire UTM blocks LJ, LK, MH and PK or a small section in blocks NG and PG. The data for block PK were added from the Bouguer Gravity Map of California, Kingman Sheet, 1:250,000 (57).

Figure B-4



Since geostatistical routines were performed on a 4 km x 4 km cell basis, the two values in each 4 km cell were averaged and included in the geologic data file for 4 km cells. This means that while gravity data is contained in the geologic data file for 4 km cells, it is not contained in the data file for the 2 km cells. In cases where only one value was provided for a 4 km cell (on the borders of sections where no data were provided), that single value was taken for the entire cell. Each gravity value is located at the northwest coordinate of the cell in which it occurs, so a slight coordinate transformation is necessary (Reference 58).

6. ENCODING GEOLOGIC AND GEOPHYSICAL VARIABLES

6.1 ENCODING SYSTEM

The variables were encoded as follows:

1. UTM blocks and cells were drawn on the CDMG geologic maps.
2. Using a fine-mesh counting grid, the proportion of each lithologic unit was estimated for each cell.
3. The length of contacts and the number, length and curvature of each type of fault was recorded for each cell.
4. Data were encoded, verified and placed on magnetic tape.

Table B-4 shows the units used for encoding each variable.

6.2 FAULT CURVATURE

The curvature of faults is measured by the smallest radius of any arc in a cell. That is, the degree of curvature in a cell is represented by the portion of a fault which, if continued to form a circle, would have the smallest radius of any such formed circles in the cell. Five classifications (Table B-5) were used: 1 indicates no curvature or a straight fault; 9 indicates a radius of one kilometer (i.e. a fault that might form a complete circle inside one cell).

Faults are not uniformly curved and often do not fit nicely into one of the categories described. Some of the situations that occur and their classification are shown in Figure B-5.

Table B-4

VARIABLE QUANTIFIERS

Variable	Numbers	Quantifier	Units
Geologic map units	1-18	Proportion	25ths
Geologic contacts	19-34	Length	0.4 km
Fault lengths	35,37	Length	0.4 km
Number of faults	36,38	Number	no units
Fault intersections	39	Number	no units
Fault curvature	40	See description in text	
Bouguer gravity*	41		mgals + 1000

* There are no gravity values in UTM blocks LJ, LK or MH and portions of NG and PG due to unavailability of data.

Table B-5

MEASUREMENT OF DEGREE OF FAULT CURVATURE

Curvature Measure	Definition
1	Straight line
3	Arc with 8 to 4 km radius
5	Arc with 4 to 2 km radius
7	Arc with 2 to 1 km radius
9	Arc with 1 km radius or smaller

Figure B-5

SAMPLE CLASSIFICATIONS OF FAULT CURVATURE